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EFFECT OF VARYING PERCENTAGES OF EXHAUST GAS ON ENGINE PERFORMANCE

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RESTRICTED BULLETIN

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INTRODUCTION

These tests were run to determine the effect that mixing engine exhaust gas with engine intake air has on fuel knock limit, specific fuel consumption, and air consumption.

APPARATUS

Tests were made with a supercharged CFR engine using manifold injection. The air flow was measured with a thin-plate orifice; fuel was measured with a balance; engine torque was measured with a 30-horsepower cradle dynamometer; and engine speed was measured with an electric timer and revolution counter.

Figure 1 shows the arrangement of the air and exhaust-gas supply systems. Exhaust gas was obtained by throttling the exhaust-gas flow from CFR engine 2 until the exhaust pressure exceeded the air pressure at CFR engine 1 air-heater outlet. Fuel flow and air flow to CFR engine 2 were measured by a calibrated rotameter and a thin-plate orifice, respectively.

The knock limit was determined by observing the oscilloscope trace of the filtered output of a crystal pressure-pickup unit.

ENGINE CONDITIONS

The following fixed conditions were maintained at CFR engine 1:

Engine speed, rpm	2000
Compression ratio	7.0
Spark advance, degrees B.T.C.	34
Number of spark plugs	2
Engine jacket temperature, °F	326
Inlet-air temperature, °F	200
Fuel	Army 100-octane

CFR engine 2 operated at a fuel-air ratio of approximately 0.068 for one set of tests and at a fuel-air ratio of 0.10 for another set of tests. The exhaust pressure was held to approximately 25 pounds per square inch.

TEST PROCEDURE

The exhaust-gas flow was computed from the following equation:

$$W = \sqrt{\frac{C\ P\ \Delta p}{T}}$$

where

W rate of gas flow, pounds per second

C constant depending upon orifice and molecular weight of gas

P absolute pressure at orifice, inches of mercury

Δp orifice differential, inches of water

T gas temperature, °F absolute

The orifice was previously calibrated with methane gas. The constant was determined from the calibration and corrected for the molecular weight of the gas at various fuel-air ratios.

The air-pressure regulator valve was adjusted to give 60 inches of mercury absolute pressure. The valve in the exhaust line of CFR engine 2 was closed down until the exhaust pressure was about 25 pounds per square inch. The exhaust-gas pressure-regulator valve was adjusted to give about 64 inches of mercury absolute gas pressure. During all tests the pressures at the air orifice and gas orifice were maintained constant. Consequently the ratio of air-orifice to gas-orifice differentials was proportional to the square of the ratio of air flow to gas flow. A graph was drawn showing the relationship between air-orifice differential and gas-orifice differential to give 5- and 7-percent exhaust gas in the intake air.

The determination of a knock-limit point was as follows: The fuel flow was adjusted to an arbitrary value, and the boost-control valve was opened until knock was obtained. The air-orifice differential was observed, and the required gas-orifice differential was read from a graph. The manual gas-control valve was adjusted to give the required gas-orifice differential. The fuel flow to CFR engine 1 was adjusted to give trace knock; and readings of pressures, temperatures, revolutions, brake scales, and time intervals were made.

Several knock points were determined by the same procedure for lean and rich mixtures. The following tests were run:

Exhaust-gas concentration (percent)	Fuel-air ratio at CFR engine 2
0	0.07
5	.07
7	.07
0	.10
5	.10
7	.10

The table shows intended values, but the actual results obtained departed slightly from these values. At least two separate tests were made at each condition in order to check the results thoroughly. Tests were also run at a constant manifold pressure of 32 inches of mercury absolute to determine the effect of exhaust gas on engine power at constant manifold pressure.

TEST RESULTS

Figure 2 shows the increase of knock-limited inlet-air pressure and indicated mean effective pressure when the engine was operated with fresh intake air, with 5 percent exhaust gas added to intake air, and with 7 percent exhaust gas added to intake air. The exhaust gas was taken from CFR engine 2 operating at a fuel-air ratio of 0.068. The specific fuel consumption did not change with changes of exhaust-gas concentration. The exhaust-gas concentration is expressed as percentage by weight of exhaust gas in the mixture relative to fresh air. A 7-percent addition of exhaust gas increased the permissible boost 9 inches and increased the permissible mean effective pressure 25 pounds per square inch at a fuel-air ratio of 0.065. This increase in power corresponds to 2.5 percent for a 1-percent addition of exhaust gas.

Figure 3 shows results of tests similar to tests shown in figure 2, except that CFR engine 2 was operating at a fuel-air ratio of 0.10. The test results are about the same as those shown in figure 2, except that the specific fuel consumption was slightly lowered with additions of exhaust gas. This fact was particularly true at lean mixtures, but this condition is of no practical importance because rich exhaust gas would seldom be added to the intake air of an engine operating on lean mixtures.

Figure 4 shows the effect of exhaust-gas concentration on the air consumption of the engine. The air consumption is decreased 5 and 7 percent, respectively, by 5- and 7-percent additions of exhaust gas. It is concluded that exhaust-gas addition lowers the air consumption in proportion to the oxygen concentration in the mixture.

CONCLUSIONS

1. Addition of 1 percent exhaust gas to intake air increased the permissible indicated mean effective pressure 2.5 percent at a fuel-air ratio of 0.065. This relation is valid to at least 7-percent addition of exhaust gas.

2. Addition of exhaust gas to the intake air of an engine lowered the air consumption at a given inlet-air pressure in proportion to the oxygen concentration in the mixture.

3. Addition of exhaust gas to the intake air did not increase the specific fuel consumption.

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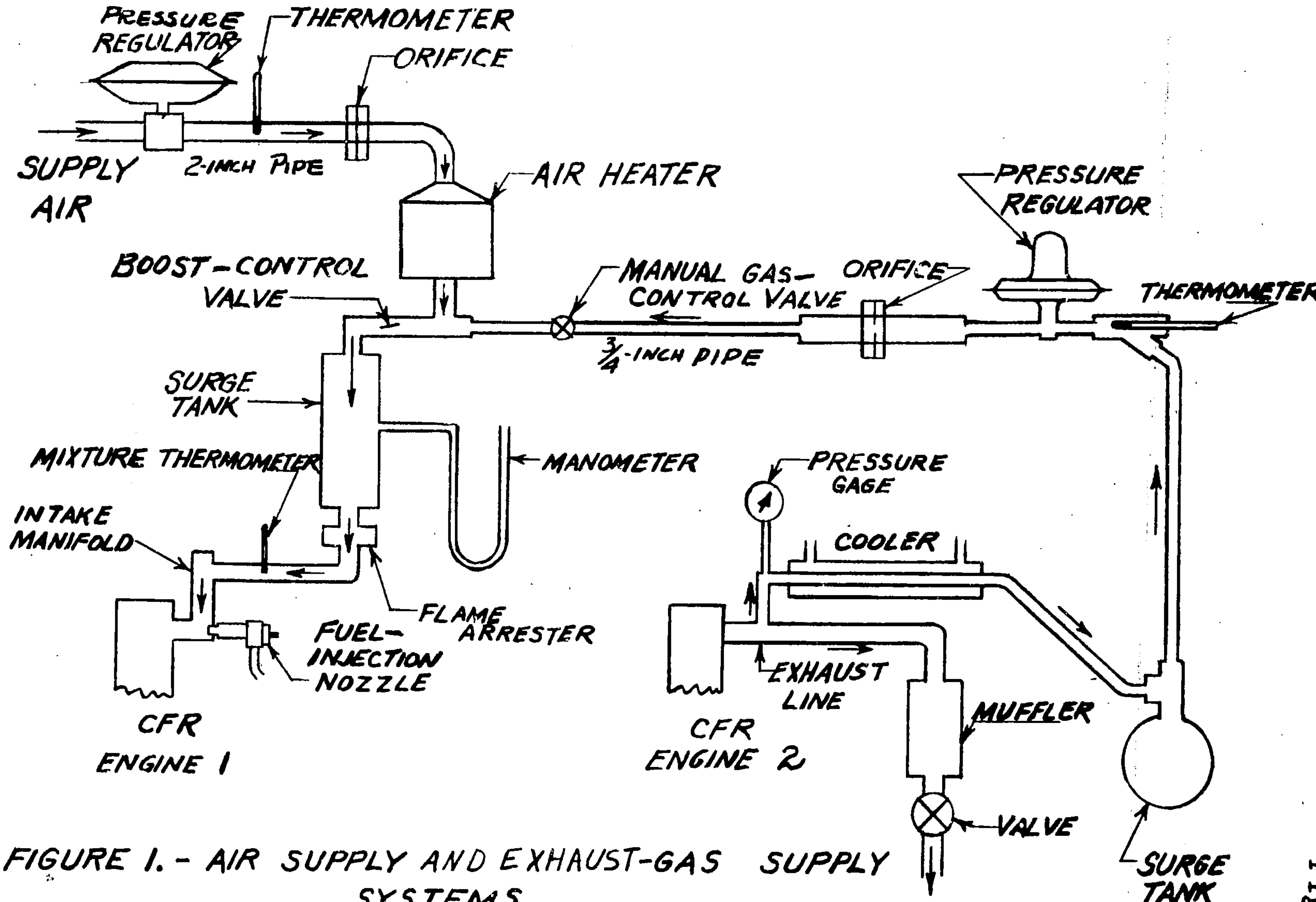

FIGURE 1. - AIR SUPPLY AND EXHAUST-GAS SUPPLY SYSTEMS.

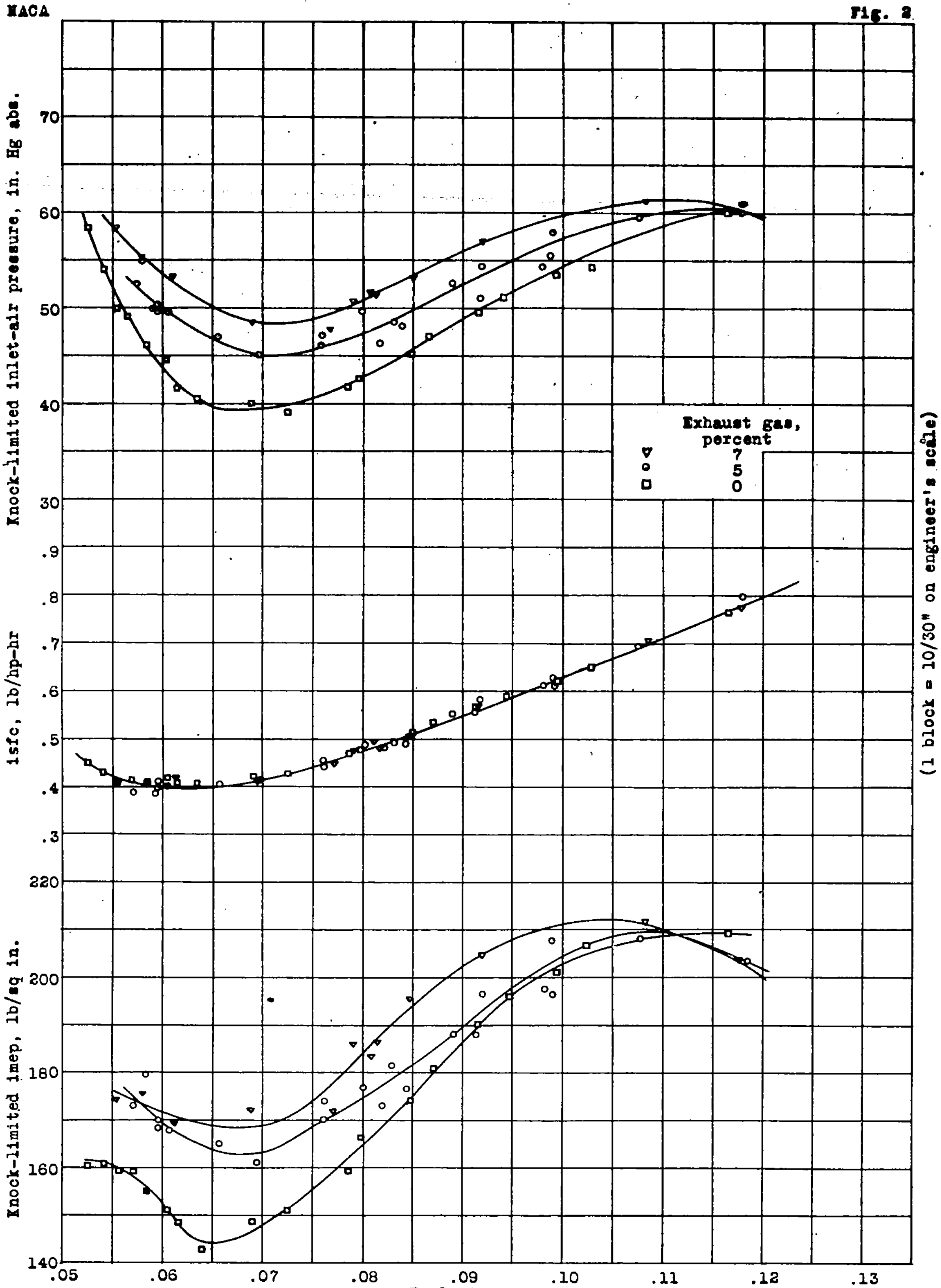

Figure 2.- Effect of exhaust gases on knock-limited indicated mean effective pressure, indicated specific fuel consumption, and knock-limited inlet-air pressure. CFR engine; fuel, Army 100-octane; compression ratio, 7.0; spark advance, 34° B.T.C.; inlet-air temperature, 200° F; coolant temperature, 326° F; engine speed, 2000 rpm; exhaust gas from engine operating at a fuel-air ratio of 0.068.

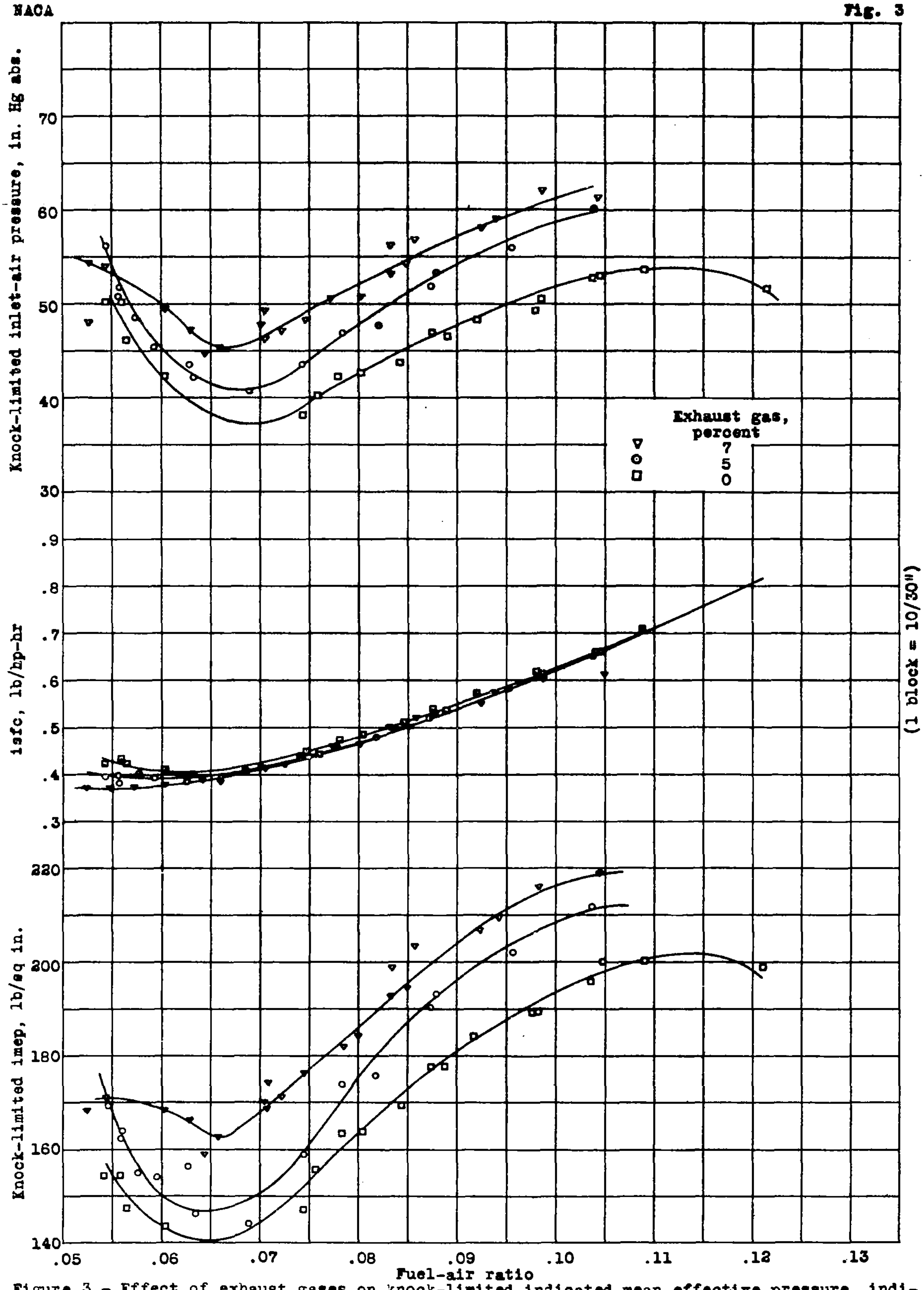

Figure 3.- Effect of exhaust gases on knock-limited indicated mean effective pressure, indicated specific fuel consumption, and knock-limited inlet-air pressure. CFR engine; fuel, Army 100-octane; compression ratio, 7.0; spark advance, 34° B.T.C.; inlet-air temperature, 200° F; coolant temperature, 326°F; engine speed, 2000 rpm; exhaust gas from engine operating at a fuel-air ratio of 0.10.